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Development of a Sustainable Community Management System Applying Conversion Technology of Forest Resources to Energy

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***Abstract*:** Today, Japan's food self-sufficiency ratio on a calorie basis has stood at lower than 40 percent. In terms of self-sufficiency, Japanese forestry is under a similar circumstance. This situation in which Japan relies too much on imports from abroad is a big problem that will shake a foundation of the nation. Both industries have been confronted with not only a decline in working population but also the labors' aging problem. Authors aim to develop a sustainable community management system for achieving a reinforcement of domestic agriculture and forestry, local production of energy for local consumption, and environmental management. In order to realize a conversion technology of forest resources to energy, there are three hurdles to overcome: 1. Quality control and cost reduction of energy, 2. Development of the wood-burner, and 3. Development of the promotion system. Regarding to these issues, Kyoto protocol and its attendant CO2 emission trading system can be the powerful driving force for accomplishing these three tasks which are the goals for a sustainable community management. Therefore, it is said that the first commitment period of 2008 to 2012 in Kyoto protocol is a unique opportunity for the dawn of the new social system and lifestyle.

***Keywords*:** a sustainable community management system, Kyoto protocol, CO2 emission trading system

1. BACKGROUND

Japan's food self-sufficiency ration on calorie basis has stood at lower than 40 percent. This fact describes the decline of the domestic agriculture. In recent years, the continuous rise in the price of petroleum has been damaging the business of greenhouse farming, and farmers are compelled to stand at the crossroad of existence.

Meanwhile, the number of domestic lumbers accounting for the local market has fallen away until 20 percent as the number of inexpensive import lumbers increases. The price of wood has dropped until one fifth of the peak price. In consequence, the profit in forestry can not be expected even though the subsidies are injected. In addition, due to an advancement of aging problem in rural regions, domestic forestry has declined and forests have been abandoned.

It is considered that these situations are not only the matter of a local economy or industry, but also the matter of a national security.

Also, it is an unavoidable matter for human beings to reduce greenhouse gas (GHG) emissions, which is a goal for United Nations Framework Convention on Climate Change (UNFCCC) and Kyoto protocol. At present, an annual crude oil consumption derived from greenhouse farming in Kochi prefecture has reached 120 thousand kiloliters. In return, there are annually 300 thousand tones of carbon dioxide discharged from this activity.

We consider that resolving these concerns will promise not only a sustainable development of regions but also the resolution of common concerns in human society.

2. OBJECTIVES

The purpose of this project is to develop a sustainable community management system applying local forest to a local energy resource by achieving following criteria; environmental management, reinforcement of local agriculture and forestry, and improvement of energy independency.

It is expected that an energy use within the growth of local forest resources will bring a new value to the forestry management. As a result, it will enable regions to improve the energy independency as well as the conditions of the local forests.

There are 3 stages to proceed in this project.

In the first stage, the primary goal is to achieve the development of the energy conversion technology of forest resources in terms of cost and combustion performance.

In the second stage, implementation of the developed technology in the management and the development of a sustainable community management system are the objectives.

For the third stage, implementation of the sustainable community management system in local society and development of the new social system are expected to proceed.

In this paper, the first stage of the project regarding the energy conversion of forest resources and the development of the wood energy heating system is reported. Also, it reports a management function regarding the prevalence of the new technology.

3. ENERGY CONVERSION OF WOOD RESOURCES

Currently, there is an annual production of approximately 25,000 tones of wood pellet in Japan. The biomass energy plants were constructed nationwide as there has been an increase in the public concerns toward environmental issues as well as the price of fossil fuel increases sharply.

However, it is considered that most of these projects were not really focusing on energy demand, but they were to deal with industrial wastes from factories and mountain forests.

In this project, forestry and agriculture, both industries have been taking roots especially in provincial areas, are closely connected in supply and demand. Therefore, we are convinced that this is a feasible project for developing a sustainable community management system.

3.1 Calorific value of pellet fuel

The most considerable factor in the energy conversion of wood resources is the price per unit calorific value against existing energy in the market. In this research, the target customer uses type A heavy oil for heating greenhouse. Therefore, it is necessary to develop a production system that has a competitive cost structure against the fossil fuel price. For that purpose, we have conducted an examination on energy contents for each type of trees. Under a certain condition, each type of pellets was burned and calorific value was measured.

Table 1 shows the result of this examination.

Table 1 Calorific value for each type of pellet

Tree Types	Type of pellet	Higher calorific value (0wt%)
Coniferous	white*(φ6mm)	4,876 kcal/kg
Coniferous	white*(φ7mm)	4,848 kcal/kg
Coniferous	white*(φ8mm)	4,913 kcal/kg
Broadleaf	white*	4,641 kcal/kg
Broadleaf	whole wood	4,646 kcal/kg
Bamboo	whole bamboo	4,769 kcal/kg

*White pellet does not contain bark part of wood.

For the result of this examination, it is confirmed that there is not much energy difference between types of wood popularly seen in Japan.

3.2 Productivity of lumbering broadleaf trees

In order to indicate the fuel production cost for each type of trees, we conducted a verification experiment on work productivity for felling, hauling, and conveying processes. The experiment took place in two different terms. First experiment proceeded for 9 days between July and September, and second was carried out for 12 days between October and November. Both experiments targeted on a broadleaf forest in a local village, and clear cutting method was adopted for both terms.

Table 2 shows work productivity per person - day for each operation.

Table 2 Work productivity (broadleaf forest)

Terms / Operations	1 Jul.-Sep.	2 Oct.-Nov.
Felling/hauling /bucking	1.45m3 /person-day	1.81m3 /person-day
Loading/forwarding /discharging	0.69m3 /person-day	1.05m3 /person-day

Picture 1 Hauling operation by a grapple machine

In this experiment, the work efficiency in term 2 was relatively higher than term 1. It is considered that this was caused by the improvement of workers skill and the deterioration of their work efficiency due to the heat of summer. In either case, it is confirmed that the work productivity for handling broadleaf trees is not as high as it is in dealing with coniferous trees according to this experiment. It is considered that the causes of this result are following reasons. Broadleaf tree has a complex configuration with its trunk and branches. Therefore, large forestry machines such as harvester and processer are normally not able to be used for dealing with broadleaf trees. Also, the operations in this experiment were not executed by skilled labors.

For a subject of future research, it is necessary to investigate the work efficiency for dealing with coniferous trees, and find the way to improve work efficiency in each operation process.

4. DEVELOPMENT OF WOOD ENERGY HEATING SYSTEM

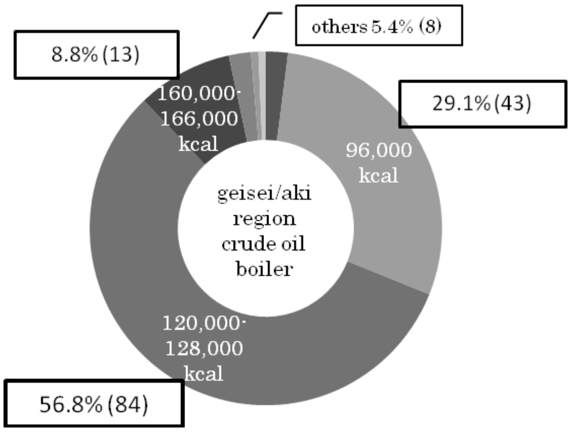
There are three critical factors for the development of wood energy heating system: performance, price, and facility. Based on these three criteria, we focused on establishing the structure of the system as simple as possible. By simplifying the system structure while having a certain level of performance, it is able to deal with system troubles easily. At the same time, it enables to lower the production cost. Therefore, it is able to meet diversified needs of small scale farmers.

4.1 Output power of the system

It is required that the wood energy heating system has to have an equal or higher output power, energy efficiency, and stability compared to the existing crude oil heating system. It seems that these qualities are getting closer to the farmers needs as the verification tests have been conducted.

About the necessary output power of the heating system, we conducted a market research in Geisei and Aki region. According to this research, it is confirmed that in these regions more than half of the crude oil boiler has an output power of approximately 120 thousand kilocalories (figure 1).

Figure 1 Market share of crude oil boiler based on the energy output in Geisei and Aki region



The wood energy heating system currently used for this examination was designed to have a maximum output power of 60 thousand kilocalories. In order to meet the farmers' needs, it is considered that development of the larger scale system will be needed.

4.2 Price of the system

Price is another criterion to measure the system by users. Ideally, the price of the wood energy heating system is equal or cheaper than the crude oil ones. However, utilization technology for wood energy is not as advanced as it is for fossil fuel energy. Therefore, it is not easy to fill in the price gap between the wood energy heating system and the fossil fuel energy heating system. In fact, the price of a wood energy heating system commonly seen in the market is several times higher than the price of crude oil ones. This has been a big obstacle that farmers cannot decide to introduce the wood energy heating system in their greenhouses.

We focused on the burner section of the heating system (Picture 2) and developed a wood energy heating system which allows farmers to use their own heaters, chimneys, and other accessories. Consequently, farmers do not have to make a huge investment for introducing this system into their greenhouses.

Picture 2 Wood-pellet burner attached to the heater

4.3 Facilities of the system

Any wood resources contain ash for the ingredients. Needless to say, ash is produced when wood is burned. Therefore, when using the wood energy heating system, users must deal with ash.

Picture 3 Ash in the dust box

In our research, it is confirmed that 5 to 10 minutes per day is needed to deal with ash produced in the wood energy heating system. The crude oil heating system does not require users to clean it so often, and people get used to it. Actually, we have heard negative opinions regarding this daily cleaning task. Reasonably, it is necessary to simplify this cleaning task for the further development of the system in order to familiarize the wood energy to users. However, as a result of pursuing facility, it seems that the distance between users and natural resources becomes larger and larger. Consequently, people do not see the real value in the natural resources but price.

Today, the limitation of natural resources is started looking over again, and renewable resources such as wood energy resources are getting public attention. We believe that this is an excellent opportunity for people to realize what really resources are again. For that mean, it is said that whether or not the wood energy heating system is accepted by farmers is a challenge by the natural resources against users.

5. VERIFICATION EXPERIMENT

Since November 21st, 2007, we have conducted a verification experiment for the wood pellet heating system at a greenhouse in Geisei village.

One of the objectives of this experiment is to measure the heating power of the system. The other objective is to compare the energy efficiency between wood and crude oil heating system under the identical circumstance. Also, we have investigated the amount of ash produced by the combustion.

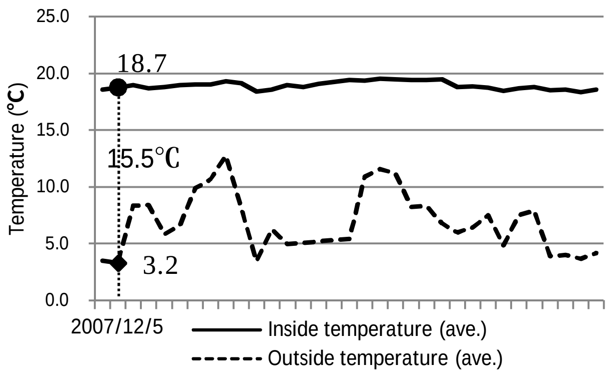
Table 3 shows the conditions of this experiment.

Table 3 Conditions of the experiment

Site	Geisei village	
Facility Scale	7.3a (Floor space: 734.4m2, Surface area: 1,185.34m2)	
Date	Dec 4th, 2007 – Feb 6th, 2008	
Runtime	17:00 – 8:00 (15 hours)	
Temp. Set	20 °C	
Plants	Green pepper	
Burner	Pellet burner	Oil burner
Heater	KT-300 (Showa Auto Heater)	
Fuel	White pellet (4,300kcal/kg)	Type A heavy oil (8,600kcal/l)

According to this experiment, the average output power of the pellet heating system was 51,898 kcal per hour, and the maximum output of 59,237 kcal per hour was observed. For this result, it is speculated that the system has a designed maximum output power of 60,000 kcal per hour. Also, it is observed that the highest increase in average inside temperature was 15.5 °C (average outside temperature 3.2°C, average inside temperature 18.7°C) higher than the average outside temperature. (Figure 2)

Figure 2 Average inside and outside temperature

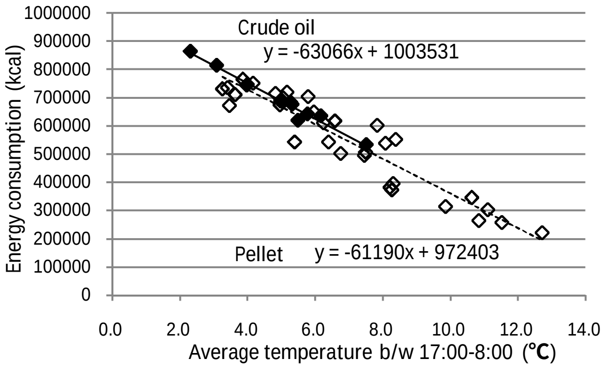


For the future, it is considered that the development of the system which has higher heating power will be needed to deal with larger scale greenhouse or a product which requires higher temperature.

Secondary, a comparison of the energy efficiency between pellet heating system and crude oil heating system was conducted under the preceding conditions. Figure 3 shows the energy efficiencies of pellet and crude oil heating system. According to this experiment, the pellet heating system has relatively higher energy efficiency than the crude oil heating system although there are some variances seen on the data of the pellet heating system.

For the future, it is necessary to stabilize the energy efficiency at any conditions. Also, the endurance of the system has to be investigated.

Figure 3 A comparison of energy efficiency



Finally, it is observed that the amount of ash produced in this experiment was 24.14 kg against total pellet fuel consumption of 4,278 kg. Thus, an average ash production ratio in this experiment was 0.56 %. Based on this result, it is expected that there will be about 180 kg of ash produced in one year per 10a greenhouse, suppose 16,000 kiloliter of crude oil is needed to grow green peppers in 10a greenhouse. Ideally, the ash should be used for fertilizing soil. For the safety use of ash, periodic tests of ash ingredients, such as chromium (VI), will be needed.

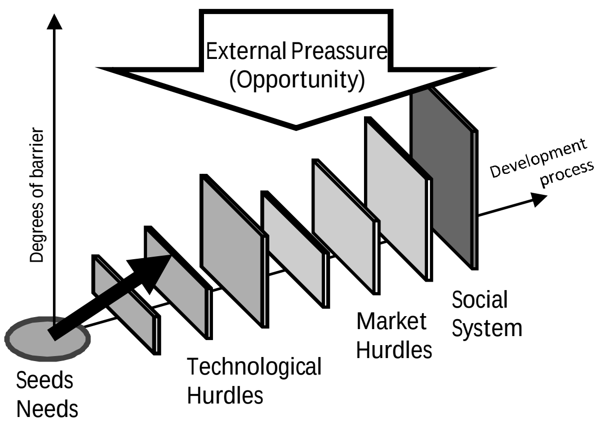
6. PREVALENCE OF THE NEW SYSTEM

In Japan, greenhouse farming has gradually spread out since 1960s. Then, the dawn of vinyl plastic made from petroleum enables farmers to easily grow early vegetables. Consequently, it is rapidly adopted as a winter agricultural technology in the regions where the temperature is relatively warm. In 1970s, crude oil heating system was developed and agricultural products are able to be produced no matter what weather or seasons.

Except for an argument about negative aspects of heating, it is regarded that the heating method is an effective way to increase the agricultural productivity under the very limited plain area like Japan. There were many difficulties to overcome in terms of technological and social aspects until the greenhouse farming has established today's position. Especially, there was a great amount of time and effort putting into the process until legislation and subsidiary systems became practical uses in the administrations. Therefore, there have to be some powerful dynamics in technology, cost, facility, or legislation when the present conditions which have strongly rooted in the society are changed.

In this case, for example, it is considered that there are technological hurdles before the practical use of the system, such as quality, performance, and cost. Similarly, there are market hurdles, such as cost, facility, and competitors, and there are hurdles in social system as well. (Figure 4)

Figure 4 An image of the development process



It is necessary to have an elaborate plan based on the strategic point of view in order to jump over these hurdles efficiently, and sometimes applying an external pressure is needed.

Presently, the market of the greenhouse farming needs an energy supply at low cost as well as the dawn of the wood energy utilization system. Similarly, forestry needs a value creation in wood. Finally, there is a social need for the reduction of greenhouse gas.

Therefore, we consider that the construction of strategic management model which is able to meet these needs at once is the most critical point in the prevalence of the new system.

7. KYOTO PROTOCOL AND ENVIRONMENT

Today, the reduction of greenhouse gas emissions has become one of the most fundamental needs for human society. It is necessary for using this global need as an external opportunity to encourage the use of wood energy.

There are many arguments for the rules or effectiveness of Kyoto protocol. At least, it is certain that Japan will be penalized if it is not able to achieve the reduction goal until the end of the first commitment period. Even though the reduction goal is achieved by applying Kyoto mechanism such as Clean Development Mechanism or Emission Trading, practically the volume of national GHG emission is not reduced. Either way, it is anticipated to be the target of criticism as far as the objective is not achieved by itself.

Meanwhile, the word “Environment” has become one of the most important themes in 21st century. For example, the concept of environmental management has been born in corporate management. Although this situation is still thread and thrum, it is certain that the phenomenon has been strongly spreading out as a global movement. In this project, it is necessary to use this movement for its driving force.

In Japan, there has been a movement to establish an emission trading market where GHG is traded among domestic corporations. As far as the system guarantees that the effort for the reduction pays off, it is expected to be the big motive for this project.

8. CONCLUSION

It is considered that the solution of the problems regarding technological aspects is relatively foreseeable in short term, though changing social system or lifestyle is extremely difficult and takes a lot of time. However, we can learn from history that the social system or lifestyle is easily changed when a global or national pressure appears in a good timing.

The society in rural regions has a highly rigid lifestyle which has been formed in the long history.

In order to accomplish our objective, development of a sustainable community management system, it is necessary to change lifestyle and social system at once. Otherwise, a great amount of time and effort will be needed.

It is expected that the impact of Kyoto protocol, which has been in effect from 2008, will be clearer as the time goes by. We consider that it is an effective way to use Kyoto protocol as an external pressure for achieving the goal as well as it is an important task to solve the technological problems in conversion of forest resources to energy.